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Abstract. The operational meteo-hydrological forecasting chain of the Liguria Region (NW Italy) is applied to a different morphoclimatic environment, such as the Emilia Romagna Region (N Italy). Modification to the chain, both in models and in procedures, are introduced to overcome problems related to medium dimension catchments ($A \approx 1000\,\mathrm{km}^2$), characterized by complex altimetry profiles and antropical interventions along the river. The main feature of the original operational procedure, that is the probabilistic approach, is maintained. Hydraulic hazard reduction through artificial reservoirs management is exploited with reference to a specific event occurred on the Reno basin (Emilia Romagna Region).

1 Introduction

The capability to predict in advance potentially critic meteorological events is one of the most important elements for civil protection (e.g. Siccardi, 1995; Direttiva PCM, 27/02/2004).

In this context, civil protection measures must refer to systems using rainfall forecast as input to drive hydrologic models as a viable alternative to the structural ways of reducing hydraulic hazards. In environments where more traditional structural measures (e.g. reservoir systems) are usually employed for flood hazard mitigation it is possible to increase lead-time through the use of a meteo-hydrological forecasting chain. The capability to predict land effects 24–48 h in advance is one of the most important elements in order to emptying artificial reservoirs, and consequently to have these volumes available to receive water flooding volumes.

In this work the integrated meteo-hydrologic forecasting chain in use at the *Centro Funzionale* (CF) of Ligura region and at *Centro di ricerca Interuniversitario in Monitoraggio Ambientale* (CIMA) was modified in order to be applied to the context of the Reno river basin. The procedure is then applied to a case study of 8 November 2002. The possible benefits deriving from its implementation are discussed.

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2 Meteo-hydrologic forecasting chain

The hydro-meteorological chain used in this work is based on the coupling of meteorological and hydrologic forecasts along the lines depicted in the following paragraphs. Meteorological forecasts are provided both by deterministic runs of the limited area model Lokal Modell and by the Limited-area Ensemble Prediction System (Molteni et al., 2001; Marsigli et al., 2001) in a probabilistic framework. Hydrological simulations are performed by applying the DRiFt model (Giannoni et al., 2005).

2.1 Lokal Modell

The Lokal Modell of the COSMO Consortium (Doms and Schaettler, 1999) is a non-hydrostatic limited area atmospheric prediction model. It is designed for operational numerical weather prediction as well as for various scientific applications on the mesoscale (50–0.5 km). A variety of physical processes (radiation, turbulence, convection atmosphere-soil interaction) are taken into account by several parameterization schemes (Ritter and Geleyn, 1992; Jacobsen and Heise, 1989; Tiedtke, 1989). The Lokal Modell offers different microphysical schemes spanning from the classical warm rain scheme (Kessler, 1969) to a graupel scheme.

2.2 Limited-area Ensemble Prediction System

The Limited-area Ensemble Prediction System (LEPS) has been developed by ARPA-SIM of Emilia-Romagna (Italy). In the modelling of intense rainfall events over complex orography the system joins, in a synergetic way, the capability of an ensemble to provide a forecast in a probabilistic

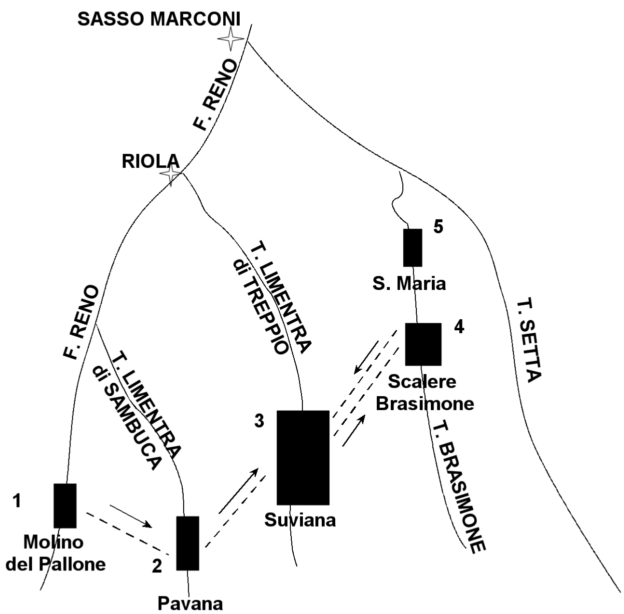

Fig. 1. Reservoir system scheme.

framework with the benefits given by a limited area model (Lokal Modell). LEPS is based on the Ensemble Prediction System (EPS) of the European Centre for Medium-range Weather Forecasts. The methodology used to generate LEPS from EPS is presented and fully described by Molteni et al. (2001) and by Marsigli et al. (2001). An ensemble size reduction technique, which allows the selection of five representative members (RMs) out of the global ensemble, is used. Subsequently, five Lokal Modell integrations at 10 km horizontal resolution are nested in the five RMs.

2.3 Disaggregation model

The downscaling model here used to fill the gap between meteorological and hydrological scales is a multifractal model based on a wavelets transform (Deidda et al., 2000). The procedure for its operational application is shown in Ferraris et al. (2002). The model disaggregates the volume forecasted by Lokal Modell and by each LEPS over a 256×256 km domain centred on the studied area of the Reno basin. For each forecast generated, 100 possible independent equally probable precipitation events with a resolution of 1×1 km and 1 h are generated.

2.4 Hydrologic model

DRiFt (Discharge River Forecast) is a linear, semi-distributed event model based on a geomorphologic approach. The model is focused on the efficient description of the drainage system in its essential parts: hillslopes and channel networks. These are addressed with two kinematic scales, which determine the base of the geomorphologic response of the basin. The morphologic module is coupled with a simple representation of soil infiltration properties (SCS-CN, 1985). Discharge at any location along the drainage network is evaluated by applying the convultion integral of the time-variant Instantaneous Unit Hydrograph, which is represented by the expression:

$$Q(t) = \int_B M\left(t - \frac{d_0(x)}{v_0} - \frac{d_1(x)}{v_1}, x\right) dx \qquad (1)$$

where: B is the drainage basin above the specified location, $M(t,x)$ is the runoff rate (mm·h^{-1}) at time t and location x, $d_o(x)$ denotes the distance from x to the closest stream channel and $d_1(x)$ denotes the distance from x to the outlet of the basin specified by the region B. Runoff is assumed to move over hillslopes at a uniform velocity v_o and through the channel system at velocity v_1 (see Giannoni et al., 2005).

In the present work, the DRiFt model, was modified in order to be able to consider the damping effect due to the dams and reservoirs characterizing the Reno river basin (see. par. 3). Figure 1 describes the reservoirs system for hydroelectrical purposes immediately upstream of Casalecchio (i.e. the section chosen for the hydrologic simulation). Table 1 describes the essential geometric and hydraulic characteristics of the reservoir system.

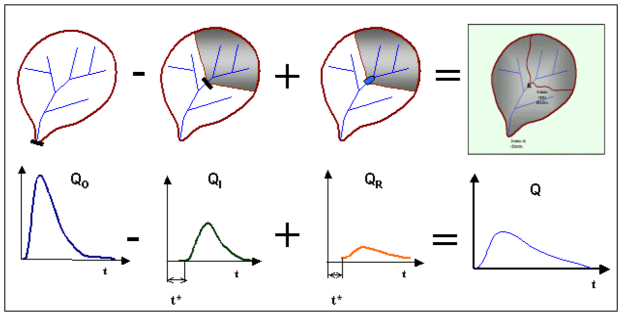

Fig. 2. Scheme for the basin response estimation.

2.4.1 Modified hydrologic model

The modified DRiFt model takes advantage of the linearity in describing runoff routing processes. This characteristic, in fact, allows a simple way to represent the effect of dams and reservoirs on the hydrologic response. The hydrologic response, Q, at the basin scale is therefore estimated according to the scheme in Fig. 2 as follows:

$$Q = Q_O - Q_I^* + Q_R \qquad (2)$$

where

- Q_O: outlet response (no reservoir effect is considered);
- Q_I: intermediate section response (no reservoir effect is considered);
- Q_I^*: intermediate section response (no reservoir effect is considered) delayed of the lag time between intermediate section and outlet along the drainage path;

Table 1. Geometric and hydraulic reservoir characteristics.

	Drained area (km^2)	Volume (m$^3 \times 10^6$)	Dam height (m)	Level (m asl)
Molino del Pallone	91	0.03	25	474
Pavana	41	1.2	45	470
Suviana	76	46.7	76.5	470
Scalere Brasimone	14.5	6.69	33.5	845
S. Maria	29.5	0.4	23.7	504

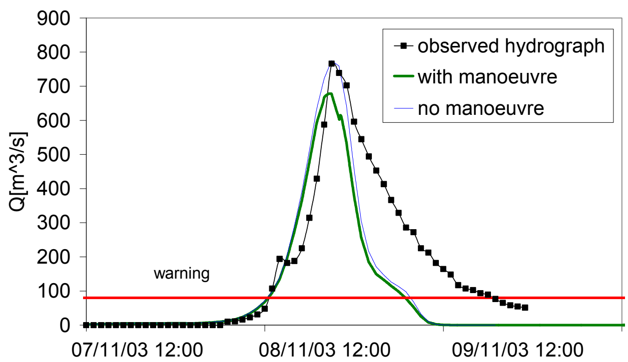

Fig. 3. Observed and simulated hydrograph using raingauges input with and without manoeuvre.

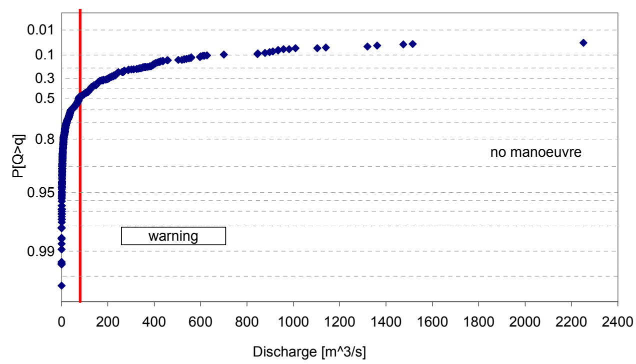

Fig. 4. Peak discharge exceedence probability plotted on a Gumbel chart without manoeuvre.

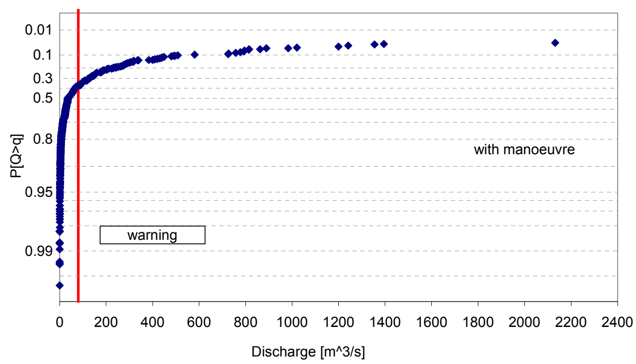

Fig. 5. Peak discharge exceedence probability plotted on a Gumbel chart with manoeuvre.

– Q_R: modified response at intermediate section (reservoir effect is considered);

Q_R is estimated according to specific characteristics of the reservoir.

3 Study case

In this work the forecasting chain has been applied to the event of 8–10 November 2003 in the Reno Basin. The Reno basin is one of the largest in Emilia-Romagna region (4930 km^2). It has a mountainous portion of 1050 km^2 at Casalecchio Chiusa section, average slope 3.7% and a wide valley portion. There are four reservoirs for hydroelectric production located in the mountainous part of the basin. These are connected each other, in particular Suviana reservoir collects water from Molino del Pallone and Pavana, that are themselves in series, while Brasimone is connected to Suviana through a pressure pipe. A fifth reservoir, Santa Maria, is located downstream Brasimone (see Fig. 1 and Table 1).

The capability of the modified hydrological model in reproducing the catchment response has been first verified using recorded rainfall series to drive the model (Fig. 3). Moreover, flood mitigation has been tested by performing a manoeuvre that reduces the filling of the two largest reservoirs Suviana and Pavana by a 20% and a 30% (this manoeuvre corresponds to the volume that could be effectively emptied with a 48 h lead-time). The forecast rainfall field through Lokal Modell of 6 November at 12:00 UTC is then used to drive DRiFt. This leads to an underestimation of the flood event due to the both incongruence among meteorological and hydrological scales, and the uncertainty in the positioning of the precipitating clusters.

To obtain a significant statistical sample, for each LEPS member, 100 possible independent equally probably precipitation fields have been simulated, using a multifractal model (Ferraris et al., 2002). For each simulation class a probability of occurrence equal to the one associated to its LEPS member is attached. Results computed at Casalecchio, with the exceeding probability curve of the peak discharge conditioned to the precipitation volume in the target area, are therefore derived from the LEPS outputs. Figures 4–5 illustrate the peak discharge exceeding probability curves by performing and not performing the manoeuvre described.

3.1 Results and Conclusions

The results of the proposed procedure show the possibility of extending the meteo-hydrological chain, operationally used at CIMA and at Liguria Region CF, to a different morphology taking into account the possibility of hydrograph lamination to mitigate the effect of floods. In the study case a modest manoeuvre reduced the peak discharge value of about 100 m^3s^{-1}. In the forecasting phase the possibility of performing reservoir manoeuvre allows us to reduce of the exceeding probability of the warning level (Fig. 5).

This work is the first step towards an integrated management of artificial reservoirs in an hydrometeorological risk mitigation context based on meteorological forecast.

The proposed hydrological model is able to take into account the role of hydraulic structures – such as dams and reservoirs – in predicting flood rising and propagation. The results are promising and suggest that this approach can be a valuable contribution within an integrated support decision system.

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References

Deidda, R.: Rainfall downscaling in a space–time multifractal framework, Water Resour. Res., 36, 1779–1794, 2000. DIRETTIVA DEL PRESIDENTE DEL CONSIGLIO DEI MINISTRI 27 febbraio 2004. “Indirizzi operativi per la gestione organizzativa e funzionale del sistema di allertamento nazionale e regionale per il rischio idrogeologico ed idraulico ai fini di protezione civile” Supplemento ordinario n.39 della GU 59 del 11.03.04.

Doms, G. and Schaettler, U.: The nonhydrostatic limited-area model LM (Lokal Modell) of DWD, Part I: Scientific documentation, Deutscher Wetterdienst (DWD), 1999.

Ferraris, L., Rudari, R., and Siccardi, F.: The uncertainty in the prediction of flash floods in the northern Mediterranean environment, J. Hydrometeorol., 3, 714–727, 2002.

Giannoni, F., Roth, G., and Rudari, R.: A procedure for drainage network identification from geomorphology and its application to the prediction of the hydrologic response, Adavances in Water Resources, in press, 2005.

Jacobsen, I. and Heise, E.: A new economic method for the computation of the surface temperature in numerical models, Contr. Atmos. Phys., 55, 128–141, 1982.

Kessler, E.: On the Distribution and Continuity of water substance in the atmospheric circulations, Meteorological Monographs, Vol. 32, American Meteorological Society, Boston, 1969.

Marsigli, C., Montani, A., Nerozzi, F., Paccagnella, T., and Buizza, R.: The Soverato flood in Southern Italy: performance of global and limited-area ensemble forecasts, Nonlin. Proc. Geophys., 10, 261–274, 2003,
SRef-ID: 1607-7946/npg/2003-10-261.

Molteni, F., Buizza, R., Marsigli, C., Montani, A., Nerozzi, F., and Paccagnella, T.: A strategy for high-resolution ensemble prediction. Part I: definition of representative members and global model experiments, Quart. J. Roy. Meteor. Soc., 127, 2069–2094, 2001.

Ritter, B. and Geleyn J. F.: A comprehensive radiation scheme for the numerical weather prediction models with potential application in climate simulations, Mon. Wea. Rev, 120, 303–325, 1992.

SCS National Engineering handbook, Section 4: Hydrology, Soil Conservation Service USDA, Washington DC, 1985.

Siccardi, F.: Rainstorm Hazard and Related Disasters in the North-West Mediterranean Region, Remote Sensing Reviews, 14, 5–21, 1995.

Tiedtke, M: A comprehensive mass flux scheme for cumulus parameterization in large-scale models, Mon. Wea. Rev., 117, 1779–1800, 1989.